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P R E S S K I T

Project: SNAP-10A (Space Nuclear Power Reactor)

TO BE LAUNCHED NO EARLIER THAN ~~MARCH 28~~ April 1, 1965

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FOLDER SNAP 10A Press Kit

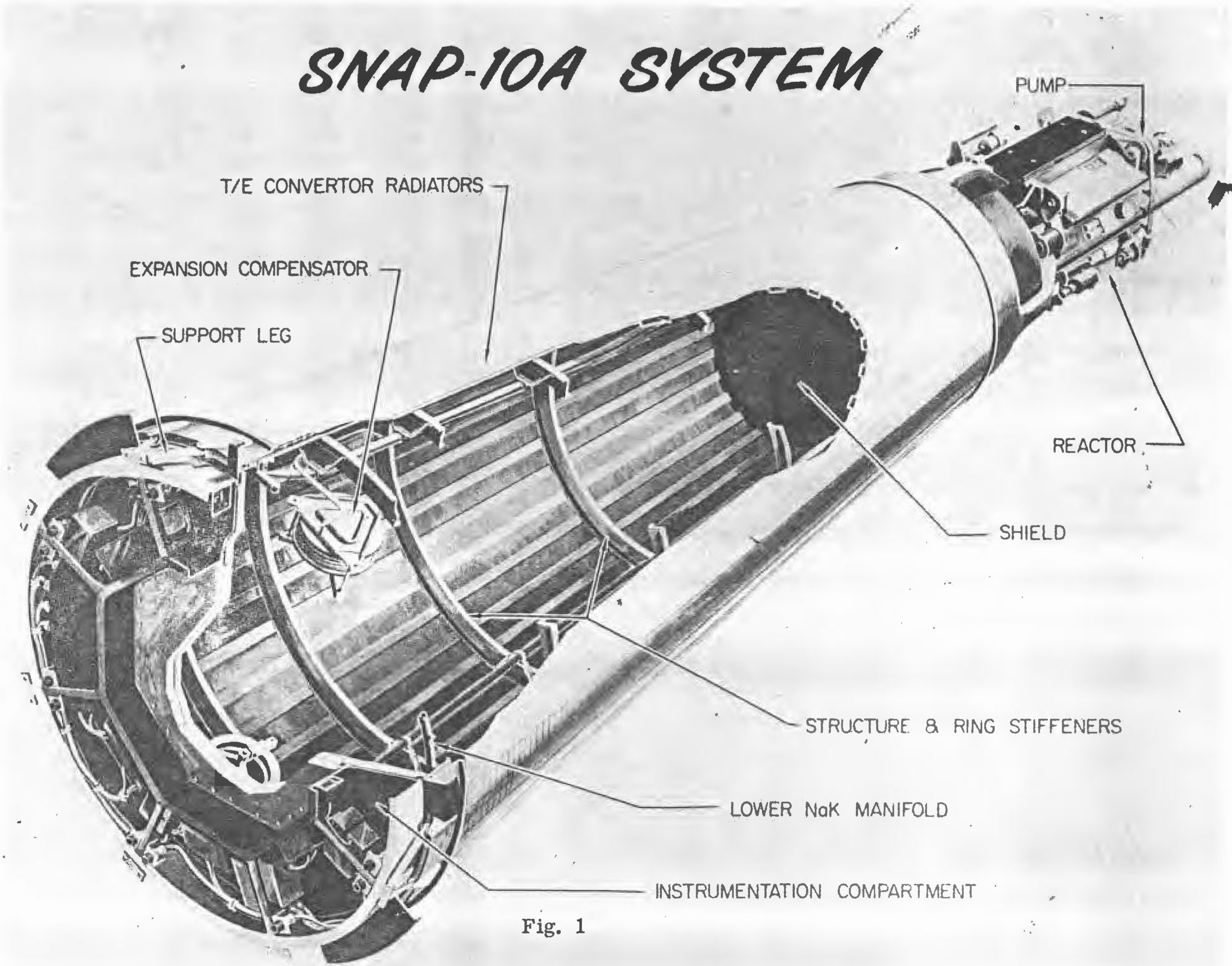
SNAP-10A SYSTEM
PUMP
T/E CONVERTOR RADIATORS
EXPANSION COMPENSATOR
SUPPORT LEG
REACTOR
SHIELD
STRUCTURE & RING STIFFENERS
LOWER NaK MANIFOLD
INSTRUMENTATION COMPARTMENT

Fig. 1

SNAP-10A REACTOR & SHIELD

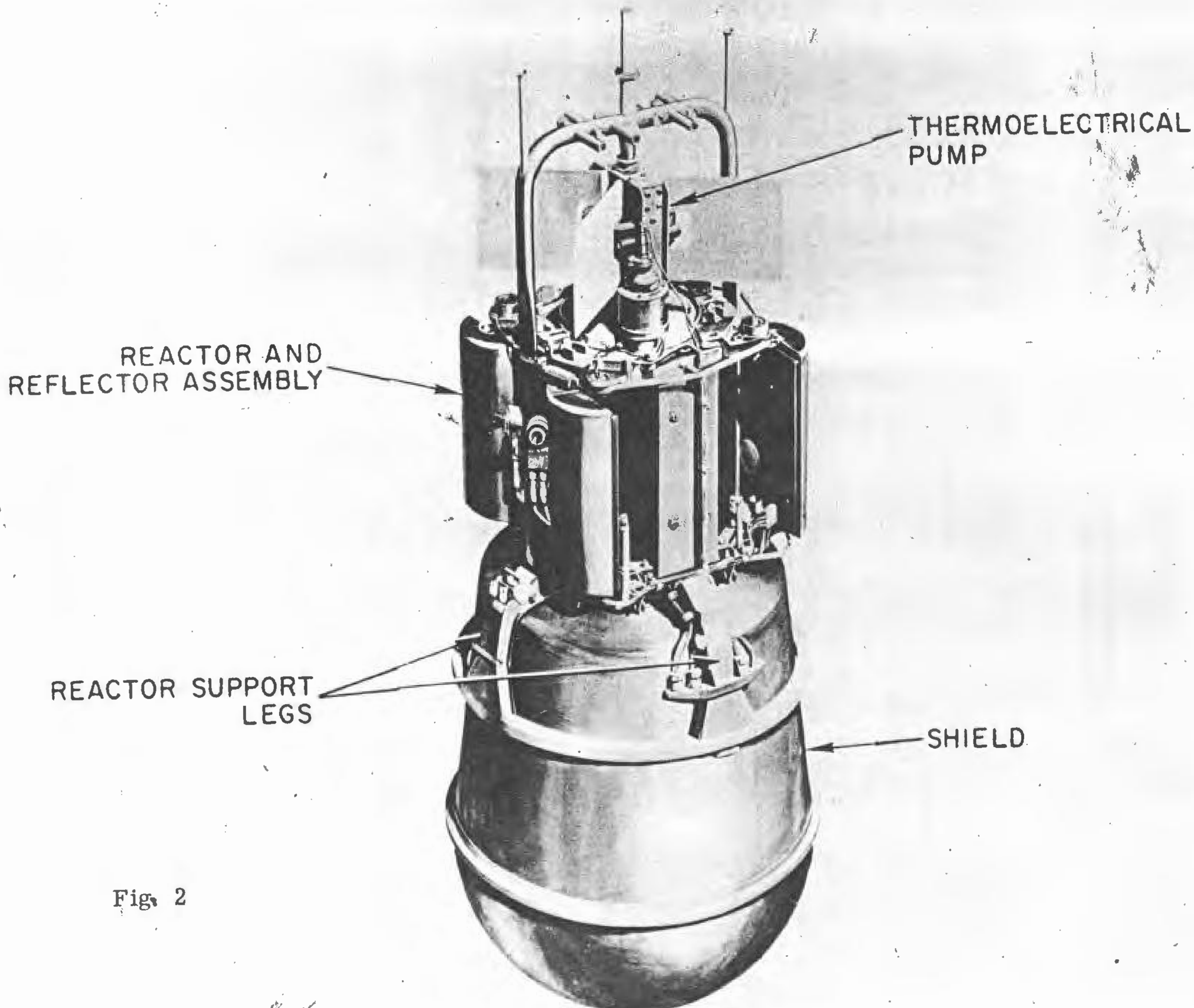

Fig. 2

SNAP-10A Fact Sheet

Thermoelectric conversion -- the conversion of heat into electricity through the use of thermocouples -- requires no moving parts and thus is suitable for use in space power systems, where high reliability is required.

The Atomic Energy Commission became interested in 1958 in applications of the thermoelectric technique to space power systems. In December 1960, the Commission established the SNAP-10A program. Under contract to the AEC, Atomics International began development at Santa Susana, California, of a SNAP-10A power system employing a nuclear reactor and a thermoelectric converter.

The complete system is pictured in Fig. 1.

The prime purpose of the SNAP-10A program is to develop a nuclear reactor power unit capable of producing a minimum of 500 watts of electricity for one year in space. Collateral aims are to demonstrate the usefulness of nuclear power in space, verify that nuclear power can be used safely in space, and provide data that will lead to development of larger and more advanced systems.

SNAP-10A has evolved through its development cycle to flight readiness. Under the encouragement of the Joint Committee on Atomic Energy of the Congress, funds were authorized for a flight test in 1965. SNAP-10A will be the first reactor to be tested in space. As the Joint Committee noted, it will be another "first in space" for the U.S. -- a demonstration of the practical use of nuclear power reactor systems in outer space.

SNAP-10A Reactor

The SNAP-10A reactor (Fig. 2) weighs only 250 pounds. At its heart is the core vessel, a steel tank 9 inches in diameter and 15 1/2 inches high. Each element (Fig. 3a) consists of a rod of fuel-moderator material, a homogeneous mixture of zirconium hydride -- the moderator -- and uranium-235 -- the fuel. The uranium-235 fuel accounts for 10 per cent of the weight of the mixture.

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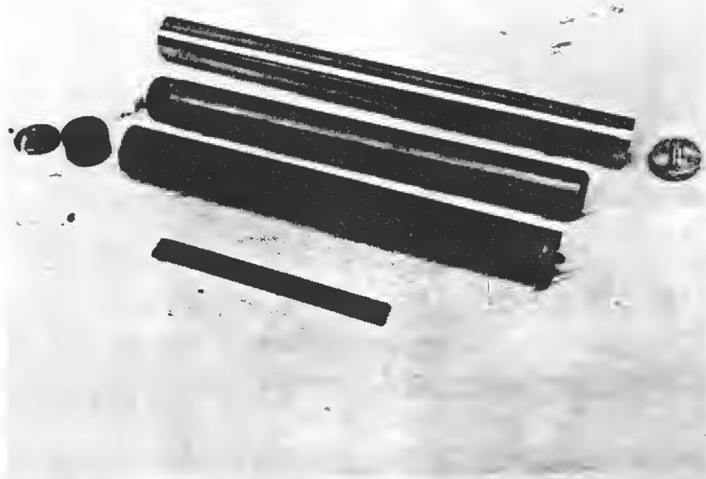
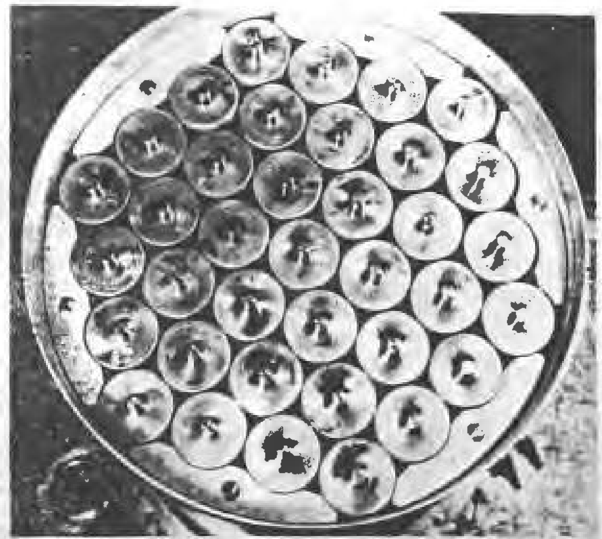
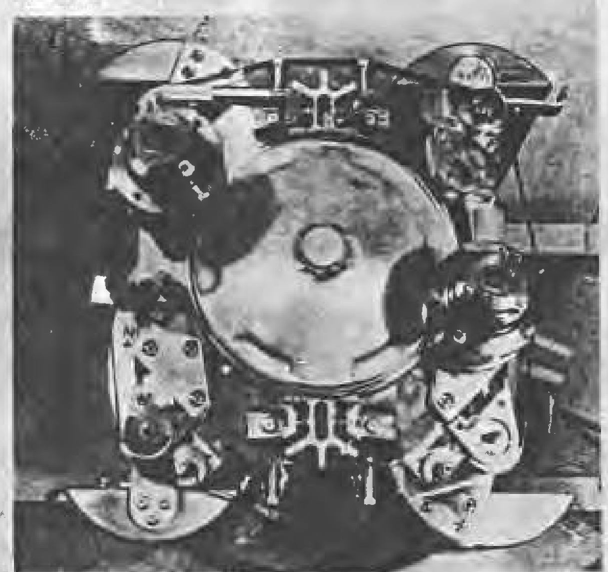


a. FUEL ELEMENT

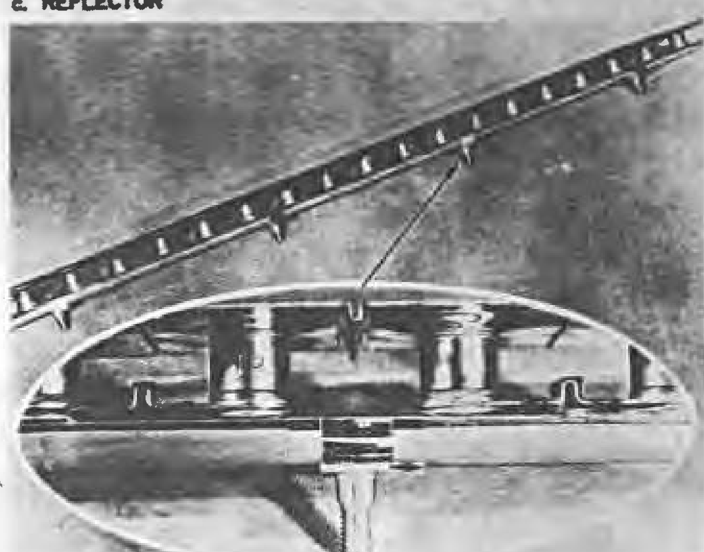


b. CORE

c. REFLECTOR



d. REACTOR (Top View)



e. THERMOELECTRIC CONVERTER MODULE

f. THERMOELECTRIC PUMP

Fig. 3 SNAP-10A COMPONENTS

Thirty-seven cylindrical fuel-moderator elements are packed vertically into the core vessel (Fig. 3b). The fuel-moderator rod is clad with Hastelloy, a high temperature nickel-based metal alloy.

The reactor coolant is a liquid alloy of sodium and potassium metals (NaK). The NaK coolant is pumped upward into the core vessel, passing through the spaces between the fuel elements and becoming heated from 872° F. to 990° F. It passes out of the core tank into tubing which leads to the thermoelectric converter. The NaK pump (Fig. 3f), mounted on top of the reactor, has no moving parts. It is powered by a thermoelectric generator. A cross-shaped radiator rejects excess heat from the pump to space.

SNAP-10A Reflector

A beryllium metal reflector about 2 1/2 inches thick surrounds the reactor core vessel (Fig. 3c). In addition to reflecting neutrons back into the core vessel, the reflector provides for reactor control. Four semi-cylindrical sections (drums) of the reflector can be rotated to vary the rate of neutron leakage, and thus to control the chain reaction.

Once a SNAP-10A reactor has reached orbit, the release of pins, acting as mechanical stops, permits the reflector control drums to be rotated inward to start the nuclear chain reaction in the core. Two drums are driven in immediately by springs. The other two are rotated very slowly by means of electric motors. Once the reactor is stabilized at a desired power level, the SNAP-10A system will use no moving parts.

The reflector is split into two halves (Fig. 4). They are held together around the reactor core by metal bands which can be broken to release the reflector either by ground command or by re-entry heating. Without the reflector, the reactor cannot operate.

SNAP-10A Converter

Thomas Seebeck discovered in 1821 that when heat is applied to the junction of two dissimilar conductors, a voltage can be measured across the cold terminals of the two materials. The Seebeck effect, or thermoelectricity, did not find practical application until the advent of semiconductor materials in the 1950's led to creation of more efficient thermoelectric materials. Because thermoelectric direct conversion involves no moving parts, it has obvious reliability benefits which are particularly valuable for space application.

The SNAP-10A thermoelectric converter (Fig. 1) is mounted around the surface of a cone-shaped corrugated titanium support structure. The NaK coolant flowing out of the reactor enters 40 parallel tubes arranged around the conical surface of the support structure. Seventy-two pellets of two types of germanium-silicon thermoelectric material are mounted along each NaK tube. (Twenty-four pellets form one module. See Fig. 3e.) Each pellet is electrically insulated from the NaK tube by an insulating disk at the base of the pellet. A copper strap joins the hot ends of each pair of pellets. An aluminum radiator plate joins the cold ends of each pair of pellets and provides a means of rejecting excess heat to space. The radiator plates are wired so as to provide a series of parallel circuits. Thus, if part of the converter becomes inoperative, the rest will continue to operate. The entire converter produces at least 500 watts at 28.5 volts.

The converter has been subjected to exhaustive tests. Some thermoelectric modules have been tested for more than 12,000 hours. Total test time for all modules is more than one-half million hours.

SNAP-10A System

The SNAP-10A reactor is mounted on top of a conical support structure. Suspended below the reactor inside the support structure is a shield (Fig. 4) of lithium hydride encased in steel. The shield protects the space vehicle payload from neutron radiation.

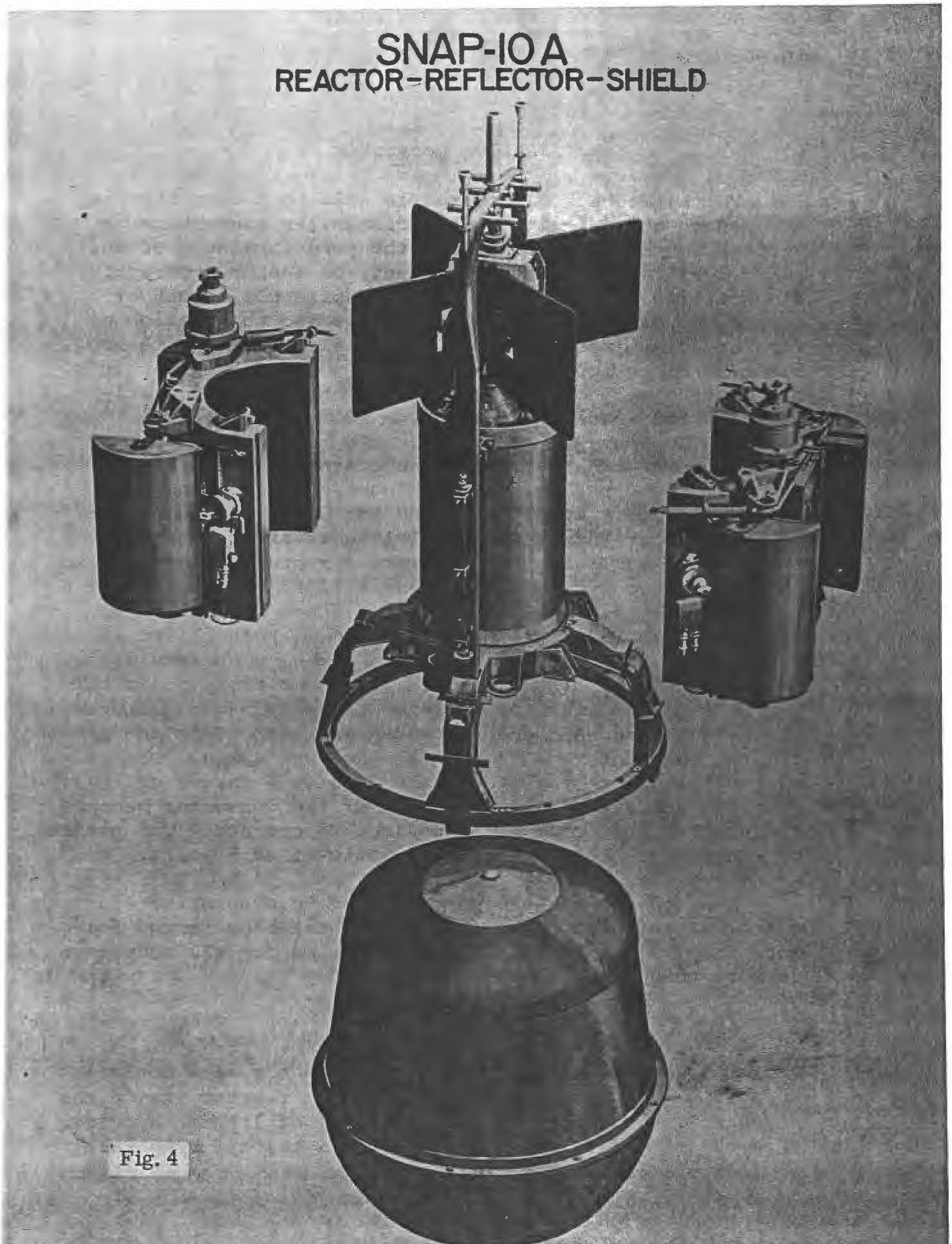


Fig. 4

Most of the electronics for SNAP-10A are mounted at the base of the support structure. Instrumentation includes an automatic start-up controller and about 75 pounds of equipment to monitor the operation of the reactor and converter.

The SNAP-10A system (Fig. 1) is 12 feet high with a base diameter of 5 feet. It weighs 970 pounds.

Development and Testing

After withstanding the rocket launching, SNAP-10A is expected to operate reliably despite the heat and radiation it creates and the effects of vacuum and possible meteoroid attack.

Great obstacles had to be overcome simply to find the materials, structures and overall design that would meet the size, weight, power and lifetime requirements for a space reactor power plant. In addition, years of development and testing were required to assure that materials, subassemblies, and the complete system would operate despite shock, vibration, heat, radiation and the peculiar effects of the absolute vacuum of space.

The conditions of launch and space operation have been duplicated to the extent possible in ground tests. The final pre-flight system qualification testing included operation of three complete SNAP-10A systems -- two of them with electrically heated NaK and the third with the reactor and converter in flight configuration inside a vacuum chamber.

Factory-to-Flight Sequence

After assembly of the system, the fuel was loaded into the core and the reactor was brought to criticality without coolant. The reactor was operated at very low power to avoid a build-up of fission products. Necessary adjustments in the fuel loading were then made. The top of the core vessel and NaK pump were welded in place and the system was loaded with NaK coolant. Electrical heaters brought the NaK to operating temperature and the reactor was again operated at low power. Final adjustments in the reflector thickness were made to assure the reactor will operate at design temperature and power.

The system was shut down and the reflectors were removed and replaced by a safety sleeve to prevent accidental operation. The SNAP-10A unit and its reflector subassembly were shipped separately to the launch site. At the site the reactor and its reflector were reunited but with various constraints to prevent operation. The system was then mated to an Atlas-Agena vehicle and final checkout activities were conducted. The ground safety constraints were then removed and the launch vehicle was fueled.

When a proper orbit is attained, a radio command to the spacecraft will initiate start-up of the power system. When the system heats up to a few hundred degrees, a heat shield which has covered the radiator-converter to prevent the NaK from freezing will be ejected. The reactor will reach full power about 24 hours after launch and will be in self-controlled power operation about 72 hours after launch.

Safety

Safety has been a prime consideration throughout the design, development, fabrication and testing of SNAP-10A. The reactor has been designed so that a chain reaction can be started only under controlled conditions. Assembly and pre-launch operations have been planned to permit unrestricted access to the system any time up to the launch without radiological hazard to personnel.

Safety during pre-launch, launch and possible abort situations is enhanced by the fact that the reactor will not be operated until the system is in a proper orbit. When the system was first assembled, it was operated at very low power to ascertain the necessity for adjustments in the fuel load. The low level of power prevented a buildup of fission products.

The system will be placed in an orbit of sufficient duration to permit decay of radioactive material before re-entry. In addition, it has been designed to facilitate break-up, burn-up and dispersal at a high altitude during re-entry.

Upon completion of its mission, the power system will be shut down by ground command.

Under the AEC's aerospace safety program, extensive tests have been conducted to confirm the safety characteristics of SNAP-10A. SNAP-10A mockups have been subjected to various possible launch abort conditions including violent impact, propellant fire and explosion.

A reactor core was tested to destruction in a tank of water at the AEC's National Reactor Testing Station to ascertain the maximum energy released under the abnormal condition of water immersion. In the test the reactor destroyed itself by undergoing a nuclear excursion.

Re-entry disassembly conditions were confirmed by a sub-orbital re-entry flight test conducted at the National Aeronautics and Space Administration's Wallops Island, Virginia, station. (See attached SNAP Program Fact Sheet for further details of the safety program.)

Future Development

The primary purpose of SNAP-10A is to prove the feasibility of nuclear power in space. For certain missions requiring long duration, operation regardless of sun-shade orientation and 500 watts of electrical power, SNAP-10A can qualify as an operational power source. More importantly, however, the SNAP-10A program has provided a foundation for nuclear space power. Technology developed under the program is already far enough advanced to permit development of systems producing up to tens of kilowatts of power. Thus SNAP-10A is the stepping stone to the large nuclear systems which must precede large-scale exploration of space and the planets.

Funding

The cost of the SNAP-10A program from July 1959, through June 1965, will be about $111,800,000 of which $83,400,000 is funded by the AEC and $28,400,000 by the Air Force. Of the total figure, $65,600,000 is for the development and testing of the nuclear space power system (including the flight systems) and $46,200,000 is for the development and testing of space vehicle equipment, booster and space vehicles and associated launch and satellite tracking services.

(more)

Ion Propulsion Engine Fact Sheet

A secondary payload of the SNAP-10A space nuclear reactor flight test is an ion propulsion engine -- a low thrust rocket. The engine was developed for the Air Force by Electro-Optical Systems, Inc., Pasadena, California.

The purpose of the test of the engine is to demonstrate that it can be operated for an extended time. The engine will be powered by a battery which will be charged by electricity from the SNAP-10A nuclear reactor power system.

The engine is 2 1/2 inches in diameter, 7 1/2 inches long and weighs 2.2 pounds.

The engine thrust is two thousandths of a pound. Although initial thrust is low, its continuous acceleration in the vacuum of space over a period of time makes possible very high speeds. On a trip to Jupiter, an ion engine could reach a speed of 100,000 miles an hour and cover the distance in less than a year. A chemical rocket would take 2 1/2 years to make the same trip.

The ion engine uses non-radioactive cesium metal as its fuel. The cesium is vaporized by a battery and is forced through pieces of hot porous tungsten pellets, shaped like buttons, which strip the cesium atoms of their outer electrons, thus leaving ions. These ions, bearing a positive electrical charge, are attracted by a negatively charged perforated metal plate which accelerates them to velocities as great as 100,000 feet per second. After passing through this plate, the ions are funneled through another plate and expelled from the rear of the rocket. At the time the ions are expelled, negative electrons are induced into the positively charged beam of the rocket to make the beam neutral and thus eliminate the possibility of its being attracted back to the negatively charged surface of the spacecraft. Such an attraction would seriously reduce the amount of thrust. It is the reaction of the spacecraft to the thrust of the positive cesium ions that makes it move forward.

Principal Contractors Associated with SNAP-10A Space Nuclear Reactor Project

Air Force - Manager of the contractor team which includes Lockheed Missiles and Space Company and General Dynamics/ Convair. The Air Force is providing the Atlas launch vehicle, launch services, and integration of the SNAP-10A nuclear power system with the Agena vehicle. The Air Force developed a radiation-hardened version of the Agena for the launch, and the ion propulsion engine, the secondary payload.

Atomics International, Canoga Park, Calif. - Prime contractor of the AEC for development of the SNAP-10A space nuclear power system. (See SNAP-10A and SNAP program fact sheets in this press kit.)

Electro-Optical Systems, Inc., Pasadena, Calif. - Builder of the ion engine, the secondary payload to be launched along with the SNAP-10A nuclear power system. Electro-Optical Systems is a contractor of the Air Force. (See ion engine fact sheet in this kit.)

General Dynamics/Convair, San Diego, Calif. - Builder of the Atlas launch vehicle. General Dynamics is a contractor of the Air Force.

Lockheed Missiles & Space Company, Sunnyvale, Calif. - Builder of the Agena vehicle, the spacecraft vehicle. Lockheed integrated the ion engine and the SNAP-10A reactor with the Agena. Lockheed is a contractor of the Air Force.

Radio Corporation of America, Harrison, N. J. - Developer of the thermoelectric modules for the SNAP-10A power system. These modules convert the nuclear reactor heat directly into electricity, producing 500 watts of electric power. (See SNAP-10A fact sheet in this kit.) Radio Corporation of America is a subcontractor of Atomics International.

#

AEC

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

March 1965

SNAP PROGRAM FACT SHEET

GENERAL

SNAP (Systems for Nuclear Auxiliary Power) is the AEC's program for the development of compact, lightweight, reliable nuclear electric devices for space, sea and land uses.

The program includes the development of techniques, materials and equipment required to apply to and advance the technology of nuclear auxiliary and propulsive electric power. Under this program, compact nuclear electric power packages (conversion of fission or radioactive decay heat to electricity) are being developed for use in satellites and space vehicles.

The technologies and resources developed for space power units are also being used in the development of nuclear auxiliary power systems for military and civilian land and sea uses. Both radioisotope-powered and reactor-powered systems are under development.*

DEVELOPMENT OF SNAP RADIOISOTOPE GENERATORS

The SNAP radioisotope program has brought forth a whole new technology of the use of radioisotopes as unique sources of compact, long-lived power. The fuel form of the several possible radioisotopes, and advanced energy conversion techniques, the detailed study of generator designs and the safety implications of the uses of these devices all contribute to a significant new technology now available for application to space, as well as to land and sea uses.

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* The SNAP numbering system uses odd numbers for devices employing radioisotopes (SNAP 1, etc.) and even numbers for devices employing reactors (SNAP 2, etc.).

(more)

GENERATORS FOR SPACE

In March 1956, the AEC initiated a program with the Martin Company, Baltimore, for the development of advanced thermoelectric and thermionic heat-to-electricity conversion devices that could be used with radioisotope heat sources, and for the exploitation of these devices in space and terrestrial power applications.

The first step in the demonstration of isotopic power was SNAP-3. The Minnesota Mining and Manufacturing Company, St. Paul, Minnesota, delivered a complete thermoelectric generator to the Martin Company in December 1958. The generator was designed to receive polonium-210 fuel capsules fabricated by the AEC's Mound Laboratory, Miamisburg, Ohio. Polonium-210, ar alpha emitter, was used because it was suitable and readily available. The Martin Company assembled and tested the complete generator, and delivered the unit to the Atomic Energy Commission in January 1959. This proof-of-principle demonstration device produced 2.5 watts with a half charge of polonium-210 fuel. It was first introduced to the world by President Eisenhower on January 16, 1959, as the SNAP-3 "atomic battery."

Later the SNAP-3 generator was modified for actual space missions. The modification required the use of plutonium-238 fuel in place of the polonium. On June 29, 1961, a 5-pound, plutonium-238-fueled thermoelectric generator was successfully placed in orbit as a power source (supplementing solar cells) in a Department of Defense navigational satellite. The event represents the world's first use of nuclear energy in space. A similar generator was launched November 15, 1961.

The SNAP-9A generator, an advanced version of SNAP-3, was developed to provide all of the power (25 watts) required by a DOD navigational satellite. Like SNAP-3, SNAP-9A is fueled with plutonium-238. The first SNAP-9A was launched in September 1963, the second in December 1963, and the third in April 1964. The first two generators are performing as expected, the third satellite failed to achieve orbit and was burned up, along with the isotope generator, upon re-entry into the atmosphere. (See pages 9-12 for information on safety aspects.)

SNAP-11 is being developed for the National Aeronautics and Space Administration. The generator is intended for use in Project Surveyor, an unmanned soft lunar exploration program. SNAP-11 will be fueled with curium-242, will weigh about 30 pounds and will provide a minimum of 25 watts of power continuously for 90-day lunar missions. The generator is scheduled for delivery to NASA in 1966. The AEC is also studying the possible use of a radioisotope thermoelectric generator on NASA's Surveyor Lunar Roving Vehicle program.

SNAP-19 is a development program to provide radioisotope thermoelectric generators for two NASA missions: Interplanetary Monitoring Probe (IMP) and NIMBUS B (a meteorological satellite). Like SNAP-9A, SNAP-19 uses plutonium-238, but SNAP-19 should be easier to fabricate and will have a lower system weight (at the same power level) than SNAP-9A.

Phase I design of SNAP-17, a 25-watt radioisotope thermoelectric generator fueled with strontium-90, has recently been completed and is being evaluated for space use. Design studies for 250-watt, strontium-90 generators have also been completed.

Proposals for SNAP-25, a 75-watt plutonium-238-fueled generator for space use, have recently been invited.

GENERATORS FOR LAND AND SEA

Land and undersea applications for isotopic power are being studied concurrently with development of the space program. These applications include unmanned weather and seismic stations for use in remote or hard-to-reach regions of the earth, navigational markers for use by ships and planes, and ocean-bottom signaling devices and oceanographic instrumentation.

The first prototype terrestrial development program is called SNAP-7. This program is essentially complete. Strontium-90 is used in the form of a very insoluble compound, strontium titanate. The SNAP-7 generators are all of a similar thermoelectric design and all but 7E have radiation shields of depleted uranium. SNAP-7E has a massive iron container which serves as both shield and pressure vessel.

SNAP-7A, a 10-watt generator, has been installed at Curtis Bay, Md., by the U.S. Coast Guard, and is providing power for a light buoy. SNAP-7B, a 60-watt generator, has been installed in a lighthouse at Curtis Bay by the Coast Guard. SNAP-7C, a 10-watt generator, has been powering a U.S. Navy automatic weather station in the Antarctic since early 1962. SNAP-7D, a 60-watt generator, was installed by the Navy, early in 1964, on an unmanned floating weather boat in the Gulf of Mexico. SNAP-7E, a 7-watt generator, is powering a Navy experimental deep-sea navigational beacon which was installed off the Bermuda coast in July 1964. SNAP-7F, a 60-watt generator, was used for demonstration at the Third International Conference on Peaceful Uses of Atomic Energy at Geneva in the fall of 1964. It is now being readied for commercial use in powering navigational aids associated with offshore oil drilling platforms in the Gulf of Mexico. Operation is scheduled for late spring 1965.

The AEC is pursuing a development program to improve on the SNAP-7 series of generators in terms of cost, efficiency, weight and reliability.

The SNAP-21 program is directed at the development of an advanced 10-watt generator for deep-sea applications. Through design improvements, a ten-fold reduction in generator weight appears feasible. The SNAP-23 program has been initiated to apply similar advances, principally in thermoelectric technology and system technology for land-based generators.

SNAP-15A, under development, is a small, rugged generator for an application related to nuclear weapon technology. Using plutonium-238 as fuel, this generator would weigh only 1 pound, and would supply 1 milliwatt of power for 5 years.

Other programs in advanced technology are also being pursued to advance the state of the art in energy conversion techniques which may be especially compatible with radioisotope heat sources.

DEVELOPMENT OF SNAP REACTORS

The AEC is developing a family of compact, lightweight, long-lived, reliable nuclear reactors to provide, initially, space power in the range of 0.5 kilowatts to 300 kilowatts. The nuclear reactor is believed to be the best device under development which will provide a long-life power source in this range for space missions without an excess weight and size penalty.

The requirement for a compact, rugged, reliable long-life space power source was envisioned in the mid-1950's. Development of compact uranium-zirconium hydride reactor systems was initiated at that time. The first use of this compact reactor as a heat source was in the SNAP-2 system. It was developed as a joint AEC-Air Force program to provide a space power system in the 3-kwe range, using a mercury Rankine power conversion system. Due to a lack of a firm requirement for such a system, the program was reoriented late in 1963. The mercury Rankine cycle and reactor technology developed under the SNAP-2 program were incorporated into a more broadly based program, designed to provide improved space nuclear power technology. (See page 8.)

Atomics International, Canoga Park, California, is the AEC's prime contractor for developing the SNAP reactors and power conversion systems. Atomics International has subcontracted with Thompson-Ramo-Wooldridge to develop the mercury Rankine cycle combined rotating unit technology and with the Radio Corporation of America to develop thermoelectric material and generator technology.

SNAP-10A

Conceptual design of a conduction-cooled, 330-pound, 300 electrical watt reactor system using thermoelectric conversion was completed in 1959 under a program designated SNAP-10. In 1960 the program was redirected to develop a more powerful 500-watt convection-cooled system using the SNAP-2 reactor. This system was designated SNAP-10A and is capable of producing 500 watts of power at a flight system weight of 950 pounds, including shielding. A flight test of the SNAP-10A system is planned in the spring of 1965.

An electrically-heated mockup of the flight system, designated FSM-1, successfully completed a continuous 90-day ground test in January 1964. The rated 500-watt output was achieved under simulated space conditions.

The first complete nuclear ground test system, FS-3, was brought to full power on nuclear heat in late January 1965. Performance testing continues.

In December 1964 an electrically heated flight qualified mockup system, FSM-4, was brought to power for long-term performance verification. The system test is continuing satisfactorily.

The first flight test unit, FS-4, has been brought to criticality and later to operating temperatures on electrical heat. All environmental testing is complete. The unit was delivered in February 1965 to Vandenberg Air Force Base for integration with the Atlas-Agena booster.

SNAP-8

The SNAP-8 program was initiated in fiscal year 1959 in response to a request from NASA to provide a high performance reactor for use in a nuclear electric space power system using a NASA-developed power conversion system. In 1964, a decision was made to continue the SNAP-8 program only through the fabrication and testing of the SNAP-8 ground prototype developmental reactor. In the original program, this reactor would have been used in the first test of the ground prototype of the complete power system.

The first SNAP-8 power reactor, designated SNAP-8 Experimental Reactor (S8ER), was developed to demonstrate rated reactor power and temperature and to measure reactor performance characteristics. Zero power experiments were started in September 1962. The S8ER successfully demonstrated power operation in December 1963. In February 1965 it achieved the equivalent of 10,000 hours of operation at or above 450 thermal kilowatts and at a coolant outlet temperature of 1,300° F., the equivalent of 4,500,000 kilowatt hours. These hours represent more than 315 days of operation of which the last 147 days were continuous. Moreover, 100 days of the operation were at a power level of 600 thermal kilowatts.

Testing of the SNAP-8 developmental reactor mockup, (S8DRM-1), an adjunct to the SNAP-8 component development effort, was begun in April 1964. S8DRM-1 is a non-nuclear mockup of the SNAP-8 reactor designed to prove compatibility of the SNAP-8 reactor system with a launch and space environment. By February 1965 the S8DRM-1 had successfully completed start-up tests, including simulated orbital start-up and launch environmental (shock and vibration) tests. It is now undergoing thermal endurance testing.

Fabrication of the SNAP-8 ground prototype development reactor (S8DS-1), which will be used in ground testing, is nearing completion.

SNAP-50/SPUR

The highest power nuclear electric system under development for space application is SNAP-50/SPUR, with a design power rating in the range of 300-1000 electric kilowatts.

It is a high temperature power system which uses a lithium-cooled refractory metal reactor heat source coupled to a potassium vapor driven turbo-alternator. Excess heat generated in the power cycle is radiated to space.

The provision of electric propulsion for deep space missions as well as large power supplies for advanced space vehicles, lunar base applications and large manned satellites will ultimately require this type of high power, low specific weight system. SNAP-50/SPUR is a somewhat longer range program than SNAP-8 and SNAP-10A. This higher performance system requires the development of an advanced reactor and energy conversion technology beyond that used in the other power plants. The program for the next 5 to 6 years calls for demonstration of the feasibility of key components of the power plant. During this time it is expected that specific applications for the system will be clearly defined and a follow-on program directed accordingly.

SNAP SYSTEMS IMPROVEMENT (SNAPSI)

The SNAP Systems Improvement Program is designed to advance the reactor and power conversion technology beyond the present SNAP-10A and SNAP-8 systems. This program consists of three parallel efforts: (1) reactor improvement, (2) advanced thermoelectric development, and (3) mercury turboelectric (Rankine) system development.

The reactor improvement program is primarily (1) to advance fuel element technology so as to upgrade SNAP-10A and SNAP-8 reactor life, power and outlet temperatures, and (2) to develop new reactor reflector-control systems to make SNAP reactors more compact. Concurrent with fuel element and reflector-control work, improvements in reactor reliability and "manrating" (suitability for manned application) of reactor systems are being accomplished.

The advanced thermoelectric development program, includes improvement of surface radiating converters to permit operation at temperatures of 1,300° F., as well as development of basic compact, flexible static converters, less difficult to integrate into a space system than the surface radiating concept.

The mercury Rankine power generating technology developed under the SNAP-2 program is being advanced. The SNAP-2 combined rotating unit has been successfully demonstrated in a simulated environment which the unit would experience from launch to orbit. An early developmental unit, still under test, has attained over eight months of accumulated operation at design conditions.

(more)

Each of three flight design units has been operated for over 2,000 hours (83 plus days) during endurance test runs at powers of 3.5 to 4.0 electrical kilowatts. One unit accumulated over 120 days of operation, and another achieved a 98-day continuous endurance run. To date over 11,500 hours of operation have been accumulated on flight design units.

Simulated remote orbital start-up of a complete mercury Rankine power conversion system was achieved over 40 times on a developmental ground test system which used certain components of actual flight design Rankine cycle power conversion system hardware.

SAFETY CONSIDERATIONS

Plutonium-238 was selected as the fuel for the first SNAP generator space missions for two basic reasons. First, it is primarily an "alpha" emitter (least penetrating of the three types of radiation) and therefore there is no need for shielding (most of the energy of the alpha particles is used to produce heat within the device). Second, the relatively long half-life (89.6 years) of plutonium-238 offers maximum advantage over other types of power supplies. (The polonium-210 used in SNAP-3 has a half-life of less than 5 months; therefore its power output dropped off rapidly.) Isotopes with very long half-lives (hundreds of years) do not have a sufficient concentration of alpha-emitting radioactivity to make them practical for lightweight isotopic power sources.

Plutonium-238 is identical chemically to other isotopes of plutonium but its nuclear characteristics are quite different. For example, plutonium-238 cannot support a chain reaction. However, plutonium can be poisonous if inhaled or ingested by living organisms over long periods of time.

The plutonium in the SNAP-9A launched in April 1964 (see page 2) burned up into very small particles which were in turn widely dispersed in the upper atmosphere. Natural dispersion and dilution in the atmosphere will continue. At the time any of the particles reach the earth the plutonium-238 will be reduced to levels far below the radiation protection guides recommended by the Federal Radiation Council.

DESCRIPTION OF SPACE RADIOISOTOPE GENERATOR SAFETY TESTS

To preclude radioisotopic contamination, fuel capsules for SNAP isotopic generators are designed to maintain their integrity under all launch pad and low altitude abort environments. Operational flight qualified capsules have been subjected to adverse environments of simulated abort fires, explosions, and chemical and mechanical interactions to demonstrate their capability to contain the fuel. While it is unlikely that the bare capsule would be freed from the generator in a launch pad abort, the conservative approach of testing the bare capsule was chosen in order to have a margin of safety. At present some of the capsules must also be designed in such a manner that during re-entry the isotopic fuel contained within the capsule will be volatilized into submicron particles. The particles would then be dispersed at very high altitudes and diffused throughout the entire earth's atmosphere. The additional radioactivity placed in the atmosphere would be negligible because of the diffusion which takes place. Tests of this design have been conducted in arc jets as well as in the actual re-entry environment.

A simulated liquid propellant missile fire test was conducted in connection with the SNAP generator program. In this test, 8,500 pounds of kerosene and 6,000 pounds of aniline and nitric acid were ignited over a simulated missile structure which held generator assemblies and bare fuel capsules. The initial flash temperature reached 5,100° F. Temperatures varying from 1,200° F. to 2,600° F. were recorded over a 15-minute period, the time a generator would be subjected to fire resulting from the launch pad abort of a liquid propellant booster. All fuel capsules were retained in the generators and no detrimental effects were noted on the capsules.

A simulated solid propellant missile fire test has also been conducted. Black powder and propane gas weighing 10,180 pounds were used to simulate a solid fuel booster vehicle propellant load. In one test 45 specimens -- including 15 generators and 36 capsules with various simulated fuel cores, and beryllium reflector samples -- were subjected to 30 minutes of burning with a maximum temperature of 2,900° F. No effects detrimental to safety were noted on any of the test specimens.

An explosion test using 1,650 pounds of TNT subjected SNAP generators and isotope containers to a shock overpressure of about 1,000 pounds per square inch. The core material was Haynes-25 alloy but similar cores were also constructed from graded aluminum for use in this test. Even the lowest grade aluminum core maintained its mechanical integrity.

In late 1964 a non-radioactive mockup of an isotope nuclear generator was used in a safety flight test, designated Re-Entry Flight Demonstration-2 (RFD-2). The primary objectives were to acquire data on generator disassembly and fuel capsule burn-up rate. This effort is part of the continuing program which includes exhaustive ground test studies to acquire data to evaluate the operational safety of power sources for space application. Initial results from the test indicate it was highly successful and that the objectives were met.

To test the ability of the plutonium-238 SNAP generator to contain its radioisotope fuel if it should fall back to earth at maximum velocity after a launching failure, bare fuel capsules were impacted at their terminal velocity against granite targets. These capsules were preheated in a furnace before impact to simulate operating temperatures. Although the capsules suffered some deformation, the tests showed that the fuel would be contained in the capsules in case of an abort. Capsules were pressure-tested to 21,000 pounds per square inch after impact to further test their integrity.

In another series of tests, generators and bare fuel capsules were dropped from airplanes. The tests were conducted to verify theoretical data on stability, mode of fall, and terminal velocity, and to verify that the ground tests were conducted under realistic conditions.

(more)

DESCRIPTION OF SPACE REACTOR SAFETY TESTS

To validate theoretical data, reactors have been subjected to the same tests of impact, mechanical and chemical reaction, fire and explosion as those conducted for the SNAP isotope generators.

In contrast to the philosophy of fuel containment for isotope generators, SNAP reactors are designed so that in case of an abort they will disassemble, thus preventing criticality (start-up) or an excursion (sudden, rapid rise in power level).

To obtain re-entry data on space reactors, a mockup of a SNAP reactor was flight-tested in May 1963. The reactor was launched by a Scout vehicle from Wallops Island, Virginia, on a 750-mile suborbital trajectory. Analysis of the test data has yielded information for design criteria to enhance safety. The test, designated Re-Entry Flight Demonstration-1 (RFD-1), was the first of a series of AEC flight tests to evaluate the safety of aerospace nuclear power systems. Analysis of the data indicates that SNAP reactors can be designed to disintegrate at high altitudes. The rates at which the fuel elements disintegrate and vaporize under re-entry conditions were learned through data obtained in the test.

A series of excursion tests of SNAP reactors is being conducted at the National Reactor Testing Station, Idaho, by the Phillips Petroleum Company under contract to the AEC to determine the consequences of an accidental, but unlikely, criticality of a SNAP reactor system. One experiment, SNAPTRAN-3, conducted in April 1964, simulated the accident that could occur should a mission involving the SNAP-10A reactor abort on launch or shortly thereafter, causing the reactor to be immersed in water. It was determined from the test that the maximum energy release to be expected from such an accident is in the neighborhood of 35 to 45 megawatt seconds. No credible radiological hazard would result to marine life or to shipping. A current series of SNAPTRAN kinetic tests will allow the results of the SNAP-10A destructive tests to be related to other reactor systems using similar fuel.

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